Carl Sagan, Scientist, Futurist

Carl Sagan (1934-1996) was an American astronomer, planetary scientist, cosmologist, astrophysicist, astrobiologist, author, and science communicator. His best-known scientific contribution is research on extraterrestrial life, including experimental demonstration of the production of amino acids from basic chemicals by radiation. Sagan assembled the first physical messages sent into space: the Pioneer plaque and the Voyager Golden Record, universal messages that could potentially be understood by any extraterrestrial intelligence that might find them.

Sagan advocated scientific skeptical inquiry and the scientific method, pioneered exobiology, and promoted the Search for Extra-Terrestrial Intelligence (SETI).

He suggested a change to Kardashev's original scale by interpolating and extrapolating the values given for types I (10^{16} W), II (10^{26} W) and III (10^{36} W), which would produce the formula K=(logP-6)/10 where *K* is a civilization's Kardashev rating and *P* is the power it uses, in watts. Humanity's civilization type as of 1973 was about 0.7, using an average power consumption of 10 terawatts (TW) as the value. See the Kardashev scale for an in-depth discussion.

Sagan also proposed an *Information Mastery* alternative to the scale. He assigned the letter A to represent 10^{6} unique bits of information and each successive letter to represent an order of magnitude increase, so that a level Z civilization would have 10^{31} bits. In this scale, 1973 Earth is a 0.7 H civilization, with access to 10^{13} bits of information. Sagan believed that no civilization has yet reached level Z, conjecturing that so much unique information would exceed that of all the intelligent species in a galactic supercluster and observing that the universe is not old enough to exchange information effectively over larger distances.

We believe this scale to be out of date, as we are already at Zettascale (10^{21}) with 18 zettabytes of total global data in 2018 and predicted to reach 175 zettabytes by 2025, making us P and then Q already. The scale talks about "unique" data but that would be impossible to calculate.

Quote from Carl:

We began as wanderers, and we are wanderers still. We have lingered long enough on the shores of the cosmic ocean. We are ready at last to set sail for the stars.

Information Mastery (Carl Sagan): Alternatively, Carl Sagan suggested adding another dimension in addition to pure energy usage: the information available to the civilization.

[li]He assigned the letter A to represent 10^6 unique bits of information (less than any recorded human culture) and each successive letter to represent an order of magnitude increase, so that a level Z civilization would have 10^31 bits. In this classification, 1973 Earth is a 0.7 H civilization, with access to 10^13 bits of information. Sagan believed that no civilization has yet reached level Z, conjecturing that so much unique information would exceed that of all the intelligent species in a galactic supercluster and observing that the universe is not old enough to exchange information effectively over larger distances.

Information storage and processing capacity is one of the aspects of civilization that has improved most dramatically since 1973, so here's the question(s):

1. What metric exactly was used to get the estimate that humanity had 'access' to 10^13 'unique bits' of information in 1973?
2. Using that same metric, how much information do we have access to in 2015?

The Kardashev Scale is one of the most popularized way to determine a civilization's ranking and advancements in whatever universe they reside in. Nikolai Kardashev introduced his scale first in 1964; however, this scale has been modified and tweaked by many different cosmologists, astrophysicists, and even science fiction authors over many years. Some of the more popular alternative approaches to the Kardashev Scale include Microdimensional Mastery by John Barrow, Planetary Mastery by Robert Zubrin, and Information Mastery by Carl Sagan. Today, our focus will be on the Information Mastery version of the Kardashev scale. In his book, The Cosmic Connection, Carl Sagan proposed an alternative approach to the Kardashev Scale. He added another dimension to the original scale in addition to the pure energy usage that was first used to characterize different civilizations. Sagan believed that the amount of information available to civilization should be an important criterion when trying to come up with a useful metric to measure different types of civilizations. So, he assigned a lettered scale from A-Z, where each letter meant an order of magnitude increase in the volume of information a civilization can hold. This information, he proposed, could be described in terms of bits, the number of yes or no statements concerning different civilizations, and the universe that such civilizations occupy. He started with a Type A civilization that he believed would have access to about 10^6 bits of unique information available to it. According to Carl Sagan, this civilization type would be extremely primitive and less than any recorded civilization in human history. On the other end of the scale, though, a Type Z civilization, he argued, would have about 10^31 unique bits of information available to it, making it the most highly advanced civilization in its universe. One thing to be aware of here is that for a civilization to advance to higher stages on this scale, it must add unique bits of information to its preexisting knowledge. For example, information is counted if a brand new technology is invented or an already existing technology is innovated. Moreover, it is important to keep in mind that the information and energy axes are not strictly interdependent here as well. This means that even a Type Z civilization would not need to be a Type 3 civilization on the original Kardashev Scale. It could be more or less advanced

than a type 3 because the focus of the Information Mastery Scale is on the amount of unique information a civilization possesses. So, In general, Carl Sagan believed that a civilization that is high on the energy scale could also be high on the information scale. But this does not necessarily have to be true. The reason for this is that Sagan argued that "[we] certainly can imagine societies that are very complex and require many more bits to characterize them than our society requires – but that are not interested in interstellar communication". This means a highly advanced civilization with numerous bits of information wouldn't necessarily want to expand outwards in its universe, classifying it lower in terms of the original energy usage criterion of the Kardashev Scale. An example of this might be a highly developed civilization like the Autobots and Decepticons from Transformers, who reside on Cybertron, a highly advanced planet, but do not venture out into space to colonize any other planets or star systems. This is the key difference between Nikolai Kardashev's original idea and Carl Sagan's interpretation of it.

Type A Information Mastery

According to Sagan, a Type A civilization is one that processes 10^6 unique bits of information. This would correspond to a primitive civilization without a written language but with a spoken one. So, civilizations such as this would be extremely limited in their knowledge. They would be more primitive than any human society we have on record, and a good starting point for the Information Mastery Scale.

Type B Information Mastery

According to Sagan, a Type B civilization is one that processes 10^7 unique bits of information. This kind of information content would be enough to start the development of a written language as well as a spoken one. Once a written language is established, the total information content rapidly explodes. In our case, the Sumerian language is the oldest linguistic record that we know of. This led to the invention of many useful things.

Type C Information Mastery

According to Sagan, a Type C civilization is one that processes 10^8 unique bits of information. With this type of information content available, this civilization would be able to create large, magnificent palace-like structures and small cities. Similar to the Indus Valley cities, a Type C civilization would be noted for its urban planning, technical and political processes concerned with the use of land, and design of the urban environment. It would be able to create brick houses, as well as a cluster of large, non-residential buildings. Additionally, this civilization will also be able to develop elaborate drainage systems, and water supply systems for its cities.

Type D Information Mastery

According to Sagan, a Type D civilization is one that processes 10^9 unique bits of information. Physicist Phillip Morrison of MIT estimated the information content of the Classical Greek civilization to be about this much, making it a Type D civilization by Sagan's ranking. The Classical Greek civilization of the Mycenaeans developed a hierarchical system, which led to many achievements. They were excellent engineers and built outstanding bridges, tombs, residences, and palaces. Moreover, their city was so large, that they had to actually build outer city walls to protect themselves. They also mastered prehistoric weapons like arrowheads and spearheads. This is exactly what a Type D civilization can accomplish anywhere else in the universe, according to this scale.

Type E Information Mastery

According to Sagan, a Type E civilization is one that processes 10^10 unique bits of information. This amount of available information would allow a Type E civilization to build detailed sculptures and architecture as well as delve in advance education and philosophy. Similar to the golden age of Periclean Athens, the philosophical ideals of this civilization would direct it towards morals, logic, and ethics. Its inhabitants would no longer need to rely on superstition, myth, or magic to explain the natural phenomena around them. This is because they would develop philosophy as a way of understanding the world around them, without resorting to religion, myth, or magic like some of the lesser civilizations on this scale. In fact, Type E philosophers would also be scientists who would observe and study the known world, their planet, seas, mountains, solar system, planetary motion, and astral phenomena just like the early Greek philosophers like Socrates, Plato, and Aristotle.

Type F Information Mastery

According to Sagan, a Type F civilization is one that processes 10^11 unique bits of information. This civilization would have mastered agriculture to the point where it would be available throughout the planet. Some inventions that would help in this monumental task would include water mills, water turbines, steam turbines, animal-driven plows, water wheels, and knowledge of crop rotation.

Type G Information Mastery

According to Sagan, a Type G civilization is one that processes 10^12 unique bits of information. With this kind of information availability, this civilization would be able to achieve many great feats. For example, the use of combustion engines, steam locomotives, steamboats, and steamships would completely mobilize it to travel across its entire home planet at a much faster pace than ever before, similar to the advances made during our industrial revolution. It would also be able to build better buildings and structures using engineered materials such as stainless steel, reinforced concrete, and Portland cement.

Type H Information Mastery

According to Sagan, a Type H civilization is one that processes 10^13 unique bits of information. Such a civilization would be capable of not only mastering ground-based travel but also achieving and mastering air travel within its home planet. Chemical propulsion rocket systems would also be within the reach of a Type H civilization. Using these methods, it could even travel to its home planet's natural satellites, if the planet had any, similar to our civilization of the recent past. Also, launching satellites into orbit would be quite common, which could give rise to Global Positioning Systems. Moreover, building space stations and setting them into orbit around its home planet is also something this type of civilization can manage. In other words, this civilization is one that could launch itself into space using rocket technology.

Type I Information Mastery

According to Sagan, a Type I civilization is one that processes 10^14 unique bits of information. This type of civilization would be one that has started exploring its Stellar System. Since its knowledge and understanding of robotics would be considerable, creating small probes and sending them to explore other planets in its Stellar System would not be much of a problem. Although a Type I wouldn't be able to send crewed space shuttles to other planets, it would have started taking keen interest in perfecting its rocket propulsion technology for such missions. For example, with the help of mega projects like the Large Hadron Collider, a Type I civilization may be able to create antimatter for use as a rocket propellant as well. It may also develop newer methods of space travel, such as Solar Sails or magnetic sails.

Type J Information Mastery

According to Sagan, a Type J civilization is one that processes 10^15 unique bits of information. Given this kind of unique information available at its fingertips, a Type J would at least be a few centuries more advanced than our civilization today. In fact, Sagan estimated that such a civilization would have had its first contact with other alien civilizations in its universe.

Type K Information Mastery

According to Sagan, a Type K civilization is one that processes 10^16 unique bits of information. With this amount of unique information availability, a Type K would be at least a millennium to several millennia more advanced than our civilization today. Similar to a Type J, Sagan viewed a Type K civilization as one that would have already mastered the dynamics of interstellar travel, thus making it one that would also have had contact with extraterrestrial lifeforms within its universe.

Type L Information Mastery

According to Sagan, a Type L civilization is one that processes 10^17 unique bits of information. A civilization possessing this much unique information content would be capable of many great feats! Apart from having all the methods of interstellar travel of previous civilizations available to it, a Type L civilization would also be able to delve into projects of terraforming certain types of planets within its galaxy. That is, planets that are reasonably close to its home planet's conditions in terms of their temperature, pressure, and atmosphere. For example, Mars-like worlds would represent these easily terraformed planets in our case. In addition, since terraforming would require advances in bioengineering, this type of civilization would be able to manipulate any DNA in order to create efficient bioengineered life forms! These could include lifeforms that are a hybrid of its existing species, or completely new for its own benefit.

Type M Information Mastery

According to Sagan, a Type M civilization is one that processes 10^18 unique bits of information. A civilization of this caliber wouldn't only be able to travel to and terraform certain types of planets, like a Type L civilization before it, but it would also be able to terraform any planet within its galaxy, regardless of its conditions. For example, terraforming worlds that are too hot, like planet Venus, or too cold like Titan, the moon of Saturn, would be considered routine for inhabitants of Type M. So, as long as a planet has a day/night cycle, the technology of this type of civilization will enable its inhabitants to terraform it with ease.

Type N Information Mastery

According to Sagan, a Type N civilization is one that processes 10^19 unique bits of information. Given its superior information content in comparison to a Type M, a Type N wouldn't just be able to terraform only rotating planets, but also be able to deal with planets that are tidally locked to their parent stars. Its technology would be so superior that it could even impart rotations on such planets if it wanted to. Moreover, because of its ability to control matter at the subatomic level, a civilization such as this would have complete control over all aspects of any given planet in its galaxy. For example, it would even have control over the electrical and magnetic fields of any planet it comes across in its travels. So, technically, a Type N civilization could even bring back 'dead' planets by jump-starting their inner cores!

Type O Information Mastery

According to Sagan, a Type O civilization is one that processes 10^20 unique bits of information. This civilization's information and energy content would be far more advanced than even a Type N, allowing it to accomplish many extraordinary feats. For example, it would be able to build Ringworlds

in space around stars, which could rotate faster than orbital velocity to create artificial gravity on its inner surface. This would allow the inhabitants of this civilization to thrive in any Stellar System regardless of whether it has any planets or any other celestial bodies! Moreover, building and sustaining space colonies for its inhabitants would also be within the capabilities of a Type O civilization. This may include hollowing out asteroids and other celestial objects to create miniature enclosed worlds, or structures resembling the Starbase Yorktown from the Star Trek universe! But these are not the only qualities of a Type O civilization.

Type P Information Mastery

According to Sagan, a Type P civilization is one that processes 10^21 unique bits of information. Given this much unique information content at its fingertips, a Type P civilization would possess knowledge and abilities that far surpass those of even a Type O. Not only would a civilization such as this be able to harness all the energy output of stars, but it would even be able to create its own stars using the available resources of its galaxy! To achieve this kind of feat, perhaps it would need to be able to move around celestial bodies, such as black holes. If it could place appropriately sized black holes within brown dwarfs or Jupiter-like planets, it could potentially cause thermonuclear reactions, igniting their fires! But this is only one way to do this; perhaps a civilization that has such vast information content available to it would have far better ways of accomplishing this kind of task that would be almost incomprehensible to our civilization today!

Type Q Information Mastery

According to Sagan, a Type Q civilization is one that processes 10^22 unique bits of information. So, if there were a galactic civilization of a million worlds, and if each of these worlds were characterized by a thousand times the information content of our terrestrial civilization, then that galactic civilization would be of Type Q. In other words, a Type Q civilization could be comparable to the Kardashev Type 3 under the assumption that the information content and the energy content of a civilization have a positive correlation, of course.

Type R Information Mastery

According to Sagan, a Type R civilization is one that processes 10^23 unique bits of information. With its given information and energy content, this is the civilization that would have broken out of its galaxy and begun intergalactic travel. It may have even fully colonized a second nearby galaxy apart from its own. This would be possible because a Type R would have refined its warp drives to the point where they would be capable of traveling hundreds of times faster than the speed of light, if not more. But of course, with such vast amounts of information availability, these types of feats would be well within the grasp of a Type R civilization.

Type S Information Mastery

According to Sagan, a Type S civilization is one that processes 10^24 unique bits of information. This amount of available information could make it possible for this civilization to unlock perhaps newer ways of space travel. For example, the inhabitants of a Type S may have developed Hyperdrives using their knowledge of higher dimensions within their universe. Now, it should be noted that while warp drives bend or manipulate space to travel, Hyperdrives usually work by stepping completely out of space and into a dimension or area that allows rapid transit from one place to another. So, Hyperdrives can in fact, be much faster than warp drives since they could allow the people of such civilizations to find shortcuts in the fabric of their universe and enable travel thousands of times faster than light! Perhaps this is why they may be able to colonize hundreds of nearby galaxies within their universe. But even with this impressive feat, we should keep in mind that although Hyperdrives are capable of faster-than-light travel, just like warp drives, they still do not permit instantaneous travel and transfers between two points. They also require a measurable

passage of time to get to one place from another similar to warp drives. Nonetheless, achieving several times faster than light travel is no small accomplishment!

Type T Information Mastery

According to Sagan, a Type T civilization is one that processes 10^25 unique bits of information. With its enormous information and energy content, such a civilization would have fully mastered both warp drives and hyperdrives. But these would be the thing of the past for a civilization of this caliber. It would have moved on to even bigger and better projects!

Type U Information Mastery

According to Sagan, a Type U civilization is one that processes 10^26 unique bits of information. Having such an immense amount of information and energy content available at its fingertips, this type of civilization would have figured out how to open and stabilize wormholes! Perhaps by suppressing quantum fluctuations, a Type U would have discovered or invented some kind of exotic matter, which experiences gravity as a repulsive force rather than an attractive one, allowing for the stabilization of wormholes. Now, using this, the inhabitants of this civilization may even create jump drives, which could tear open ship-sized wormholes connecting any two points in the universe, allowing near-instantaneous travel. This would allow a civilization of this caliber to colonize and control its entire supercluster! Which means, it would have expanded to over 100,000 galaxies or 200,000,000 light-years in diameter! Now, that would be an incredible feat, to say the least.

Type V Information Mastery

According to Sagan, a Type V civilization is one that processes 10^27 unique bits of information. A civilization possessing this much information and energy content would have technology that is way beyond even a Type U. For example, the inhabitants of Type V may have mastered all the methods of teleportation, which would eliminate the need for any spaceship travel, at least to relatively nearby destinations. Perhaps, they may also have answered all the philosophical questions related to such methods of travel. Of course, given such a vast amount of information content, it is no wonder that a civilization like this may have answered most, if not all, of the fundamental questions about life and the universe.

Type W Information Mastery

According to Sagan, a Type W civilization is one that processes 10^28 unique bits of information. Given such an immense amount of information and energy content, such a civilization would be capable of many incredible feats. It would be able to exploit exotic or fantastical physical phenomena such as cosmic strings, along with dark matter and the like. Understanding and manipulating these cosmic strings may allow such a civilization to twist and bend the fabric of space-time itself! It may also enable it to unlock some of the deepest mysteries and transformational periods of its universe. This would be extremely beneficial since it could allow such a civilization a lot more freedom to expand and colonize its universe than ever before. So, using its knowledge of these fantastical physical phenomena, a Type W civilization's sphere of influence could be around 25 billion light-years in diameter, assuming, of course, that its visible universe is around 100 billion light-years across.

Type X Information Mastery

According to Sagan, a Type X civilization is one that processes 10^29 unique bits of information. Having this much information and energy content, this civilization would have very little left to uncover in its universe. It would possess knowledge of things such as the origins of life and the ultimate fate of its universe, along with all the other technology to manipulate the very fabric of its

space-time continuum, similar to a Type W. The inhabitants of this civilization may also be very close to cracking the code of dark energy and other hidden mysteries of the universe. With such extensive knowledge and technology, a Type X civilization would have colonized about 50 billion light-years across, which would be about half of its visible universe!

Type Y Information Mastery

According to Sagan, a Type Y civilization is one that processes 10^30 unique bits of information. With such an incredibly vast amount of available information and energy content, a Type Y civilization would be nearing the limits of how much progress a civilization can make under this model. For instance, a civilization of this caliber may even control dark energy, allowing it to further manipulate its entire universe at will. It would even have control over entropy, giving it the freedom of making absolutely any object or person immortal if it wanted to. Perhaps instantaneous transportation of its inhabitants to any place within its universe may also be a possibility for a Type Y civilization using laws of physics that are currently unknown. This would allow such a civilization to colonize a large chunk of its visible universe up to 75 billion light-years across, assuming the visible universe to be about 100 billion light-years in diameter.

Type Z Information Mastery

According to Sagan, a Type Z civilization is one that processes 10^31 unique bits of information. He estimated that an advanced civilization that can harness the information content of at least billions of interconnected Type Q civilizations would qualify that civilization as a Type Z. So, a civilization of this caliber would be capable of controlling and manipulating things at the Planck length, giving it absolute control over its universe! Since the entire universe for this civilization would be at its disposal to manipulate however it chooses, creation or destruction of planets, stars, black holes, galaxies, or even galaxy clusters would all just be a day's work for this type of civilization. Moreover, all the questions about life and the universe would be known to a Type Z civilization. Nothing would be a mystery to it since every corner of its universe, along with all lifeforms within it, would have been mapped out. For this reason, a Type Z civilization would have expanded and colonized its entire visible universe!

Microdimensional

Microdimensional mastery was proposed by John Barrow, based on the fact that humans (or other civilizations) have found it more cost-effective to extend any abilities to manipulate their environment over increasingly smaller dimensions rather than increasingly larger ones, therefore reversing the classification downward from Type 1-minus to Type Omega-minus.

Microdimensional categories of the Kardashev scale:

Microdimensional	Corresponding	Description
Type 1-minus	K0.3	capable of manipulating objects over the scale of themselves: building structures, mining, joining, and breaking solids
Type 2-minus	K0.7	capable of manipulating genes and altering the development of living things, transplanting or replacing parts of themselves, reading and engineering their genetic code
Type 3-minus	K0.7	capable of manipulating molecules and molecular bonds, creating new materials
Type 4-minus	K0.9 to K1	capable of manipulating individual atoms, creating nanotechnology on the atomic scale, and creating complex forms of artificial life
Type 5-minus	K1 to K2	capable of manipulating the atomic nucleus and engineering the nucleons that compose it; picotechnology
Type 6-minus	K3	capable of manipulating the most elementary particles of matter (quarks and leptons) to create organized complexity among populations of elementary particles; femtotechnology
Type Omega-minus	K4	capable of manipulating the basic structure of spacetime and the fabric of reality

According to this scale, humans, having wide expertise in various branches of chemistry and biology, have passed the stage of Type 3-minus. Type 4-minus technologies (that have had practical and widespread applications) have been seen in areas like nanotechnology, semiconductors, materials science , and genetic engineering, whereas Type 5-minus has seen large-scale application in the field and subfields of nuclear physics. Type 6-minus has had tentative research in the field of particle physics with particle colliders such as the Large Hadron Collider.

See also